RECENT RAPID REGIONAL CLIMATE WARMING ON THE ANTARCTIC PENINSULA

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Abstract. The Intergovernmental Panel on Climate Change (IPCC) confirmed that mean global warming was $0.6 \pm 0.2\,^{\circ}$C during the 20th century and cited anthropogenic increases in greenhouse gases as the likely cause of temperature rise in the last 50 years. But this mean value conceals the substantial complexity of observed climate change, which is seasonally- and diurnally-biased, decadally-variable and geographically patchy. In particular, over the last 50 years three high-latitude areas have undergone recent rapid regional (RRR) warming, which was substantially more rapid than the global mean. However, each RRR warming occupies a different climatic regime and may have an entirely different underlying cause. We discuss the significance of RRR warming in one area, the Antarctic Peninsula. Here warming was much more rapid than in the rest of Antarctica where it was not significantly different to the global mean. We highlight climate proxies that appear to show that RRR warming on the Antarctic Peninsula is unprecedented over the last two millennia, and so unlikely to be a natural mode of variability. So while the station records do not indicate a ubiquitous polar amplification of global warming, the RRR warming on the Antarctic Peninsula might be a regional amplification of such warming. This, however, remains unproven since we cannot yet be sure what mechanism leads to such an amplification. We discuss several possible candidate mechanisms: changing oceanographic or changing atmospheric circulation, or a regional air-sea-ice feedback amplifying greenhouse warming. We can show that atmospheric warming and reduction in sea-ice duration coincide in a small area on the west of the Antarctic Peninsula, but here we cannot yet distinguish cause and effect. Thus for the present we cannot determine which process is the probable cause of RRR warming on the Antarctic Peninsula and until the mechanism initiating and sustaining the RRR warming is understood, and is convincingly reproduced in climate models, we lack a sound basis for predicting climate change in this region over the coming century.

1. Introduction

The Intergovernmental Panel on Climate Change (Houghton et al., 2001) has determined that *global warming*, the average warming of the surface of the planet, was $0.6 \pm 0.2\,^{\circ}$C during the 20th century* and that 'most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations'. Moreover, in the past few decades global mean temperature was the highest of any period in the last millennium (Mann et al., 1999). These are impressive headline figures, but they conceal the real complexity of contemporary *climate change*, which is seasonally- and diurnally-biased (Chapman and Walsh, 1993; Horton, 1995), decadally variable (Nicholls et al., 1995) and geographically patchy (Hansen et al., 1999).

* Here we use the terms *global warming* to denote the mean rate of warming of the planet, and *climate change* to denote all changes in all climate variables with time. Following the Intergovernmental Panel on Climate Change, we intend neither term to imply a root cause in natural variability or human activity.

Climatic Change **60:** 243–274, 2003.

8. Conclusions

Many studies have demonstrated the great complexity in global trends in atmospheric temperature over the past 1000 years. We have identified three areas of recent rapid regional (RRR) warming, which all occur at high latitudes and in which warming has been several times the global mean. These areas of RRR warming are in different climatic regimes and there is no reason to suppose that they have a common origin. To understand what causes each RRR warming we will need to understand the climate processes that have caused them at a regional level. As a step towards this we have presented a detailed discussion of the RRR warming on the Antarctic Peninsula.

Station records show that the Antarctic Peninsula has warmed at $3.7 \pm 1.6\,^{\circ}\mathrm{C}$ $(\mathrm{century})^{-1}$, several times the rate of *global warming* and quite different to most of the other station records from the Antarctic continent. In fact, when considering the long-term station records from Antarctica, we find no evidence for a 'polar amplification' of climate change elsewhere in Antarctica. Rather, we see a regionally variable pattern, with an underlying warming not significantly different to the global mean.

The analyses highlight the lack of any long-term station records in the Amundsen Sea sector of Antarctica, and absence of direct evidence for warming in this area. However, sea-ice duration has declined around this portion of coast during the last three decades suggesting that there may well be changes in this area.

RRR warming on the Antarctic Peninsula is having documented impacts on, terrestrial flora, seasonal snow cover, lake ecology, penguin distribution, ice-shelf distribution, glacier thickness and sea-ice duration. We have argued that three climate proxies, oxygen-isotope records from ice cores, marine sediments recording the presence and absence ice shelves, and the occupation of penguin rookeries, all seem to suggest that no similar warming has occurred for at least 1800 years, making the RRR warming exceptional in this period.

If the RRR warming on the Antarctic Peninsula is exceptional over this timescale, it is unlikely that the present changes can be explained simply as a mode of natural variability; rather we must consider what outside driver caused the change. Comparison of the magnitude of the warming, with a recent assessment of the change in sea-ice duration clearly indicates that warming is linked to sea-ice conditions, but here cause and effect have not yet been identified. We believe that any combination of three distinct candidate-mechanisms could have caused the RRR warming; changing oceanographic circulation (e.g., an intrusion of CDW onto the continental shelf), changing atmospheric circulation (perhaps linked to ENSO, Trenberth and Caron, 2000), or local greenhouse warming amplified by sea-ice processes. The last of these appears to be consistent with mid-tropospheric temperatures trends, the seasonality of surface trends and the exact positioning of the greatest warming signal. However, until we understand which candidate-mechanism is responsible, we cannot predict the likelihood that the RRR warming will continue.

Among the local impacts of continued RRR warming would be, continued retreat of ice shelves, retreat of low-altitude glaciers, increased seasonality in some snowfields. Biological habitats will continue to undergo changes in extent, although it is unlikely that any particular species would be seriously threatened (Convey, 2001). Similarly, there would probably be few global impacts resulting from changes on the Antarctic Peninsula (Anisimov et al., 2001) – some contribution to sea level change is expected, although its sign is unpredictable at present.